DESIGN OF MICROSTRIP ANTENNA BASED ON DIFFERENT MATERIAL PROPERTIES

ANIS NABIHAH BINTI IBRAHIM

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Special Dedication For…

My Husband,

Mr. Muhammad bin Mohamed Salleh,

Thank you for your sacrifices,

May Allah bless our marriage.

My Parents, Father In Law and Mother In Law,

Mrs. Azizah binti Samat and *Mr. Ibrahim bin Daud*,

Mr. Mohamed Salleh bin Kalil and *Mrs. Siti Haida binti Othman*,

Your sacrifices will always be remembered,

May Allah bless all of you.

My Beloved Family,

May Allah bless our lives,

May Allah grant our health, wealth and faith.

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ABSTRACT

Microstrip antenna has several advantages compared to conventional microwave antenna. These type of antenna are light weight, low volume and thin profile configurations, which can be made conformal. The cost of fabrication is also low and can be manufactured in a large quantities. This project will discuss about the microstrip antenna. The aim of this project is to design a microstrip antenna by using Flame Retardant 4 (FR4) substrate and Roger 4350 substrate which will be operating in Wireless Local Area Network (WLAN). The frequency chosen for the microstrip antenna is 2.4GHz and it has been chosen from IEEE 802.11 which is for the Wireless Fidelity (WiFi) network. This project is divided into three major parts which are calculation, simulation and hardware design. Computer Simulation Technology (CST) microwave studio software used to analyze the radiation pattern of the antenna before fabricated the antenna. Vector Network Analyzer (VNA) used to measure the fabricated antenna to obtain the measurement result. The simulation and measurement results shows a little bit differences for both of the material substrates. Comparison between simulation and measurement result has been made.

ABSTRAK

Antena Mikrojalur mempunyai beberapa kelebihan berbanding dengan Antena Gelombang Mikro Konvensional. Antenna Mikrojalur mempunyai kos fabrikasi yang rendah dan boleh dihasilkan dalam kuantiti yang banyak. Projek ini memfokuskan kajian tentang Antena Mikrojalur dan untuk merekabentuk antena tersebut dengan menggunakan FR4 dan Roger4350. Frekuensi yang dipilih bagi antenna ini adalah 2.4GHz yang telah dipilih dari IEEE 802.11 bagi rangkaian WiFi. Projek ini dibahagikan kepada tiga bahagian utama iaitu pengiraan, simulasi dan fabrikasi. Perisian komputer yang digunakan bagi merekabentuk antena ini adalah CST dan digunakan untuk menganalisis corak sinaran antena sebelum difabrikasi. VNA digunakan untuk mengukur antenna yang telah difabrikasi bagi memastikan antena tersebut boleh berfungsi dalam frekuensi yang telah ditetapkan. Keputusan simulasi dan pengukuran mununjukkan terdapat sedikit perbezaan bagi kedua-dua jenis bahan yang digunakan. Perbandingan diantara hasil simulasi dan hasil pengukuran telah dibuat.

CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF SYMBOL AND ABBREVIATIONS

ε_r	-	Dielectric relative constant
μ_o	-	Permeability in free space
ε_{eff}	-	Effective dielectric constant
ε_0	-	Dielectric constant in free space
Ώ	-	Ohm
Γ	-	Reflection coefficient
ΔL	-	Patch length extension
B	-	Bandwidth
C	-	Speed of light 3 x 10^8
W	-	Width
L	-	Length
F	-	Frequency
dB	-	decibel
VNA	-	Vector Network analyzer
MHz	-	Megahertz
GHz	-	Gigahertz
VSWR	-	Voltage standing wave ratio

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In high-performance like aircraft, spacecraft, satellite and missile application, where sizes, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, low profile antenna may be required. Presently there are many other government and commercial application, such as mobile radio and wireless communications, which have similar specifications. Microstrip patch antenna can be used based on these requirements. This antenna are low profile, conformable to planar and non-planar surface, simple and low cost to manufacture by using a modern printed-circuit technology. Microstrip antennas consist of a patch of metallization on a grounded substrate. These are low-profile, lightweight antennas, most suitable for aerospace and mobile applications. Because of their low-power handling capability, these antenna can be used in low-power transmitting and receiving applications [1].

Wireless technology is a truly revolutionary paradigm shift, enabling multimedia communication between people and devices from any location. Wireless communications is by any measure, the fastest growing segment of the communications industry. As such, it has captured the attention of the media and the imagination of the public [2]. Modern wireless communication systems require low profile, lightweight, high gain and simple structure antennas to assure reliability, mobility and high efficiency. There are many parameters are important in designing the microstrip antenna. Dielectric substrate is the main parameter in design purpose.

One types of wireless communication at 2.4GHz is Wireless Fidelity (WiFi). It is enable devices such as smartphone, personal computer, video game console or digital audio player can connect to the internet if within range of a wireless network connected to the internet. The microstrip antenna was drawn the maximum attention of the antenna community in recent year. A microstrip antenna is very simple in construction using a conventional microstrip fabrication technique. Microstrip antennas consist of a patch of metallization on a grounded electric substrate. There are low profiles, lightweight antennas, most suitable for aerospace and mobile applications. The conducting patch can be any shape but the most commonly used configurations are circular and rectangular configurations.

Deschamps first proposed the concept of microstrip antennas in 1953 but practical antennas were developed by Munson and Howell in 1970s [3]. Increasing requirements for personal and mobile communications has made the microstrip antennas very important. Microstrip antenna are becoming a popular choice for portable wireless system since they are light weight, low cost and easily manufacturable [4].

It is also can be applied in Wireless Local Area Network (WLAN) application. Wireless Local Area Networks (WLANs) use electromagnetic radio waves to transmit data between computers in a Local Area Network (LAN), without the limitations set by wired network cable or phone wire connection. These 802.11 Wireless Local Area Network (WLAN) systems may operate at 2.4GHz [4].

Microstrip patch antenna can take a variety of forms, but the basic element consists of a single patch of conductor on the upper surface of a grounded dielectric substrate. The patch radiates efficiently when it is resonant, which generally means that some characteristic dimension of the patch is nearly equal to one-half wavelength in the substrate medium [5].

The shape of the patch can be rather arbitrary, but rectangular and circular patches have several desirable characteristics and more often used in practice [5]. Figure 1.1 shows the side view of simple microstrip patch antenna. The simple microstrip antenna consists of three layers which are substrate, patch layer and ground layer.

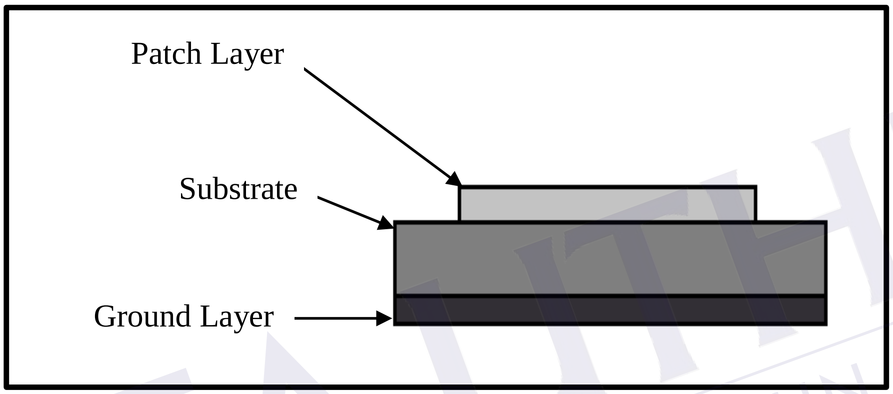

Figure 1.1 : Side view of microstrip patch antenna.

1.2 Problem Statement

Antenna is develop in order to fulfill the problem occur and upgraded the antenna for the advanced technologies. A conventional antenna is very hard to design compared to microstrip antenna. A conventional antenna is very costly and quite heavy but the microstrip patch antenna has a simple structure and quite easy to fabricated. There are many shape of microstrip patch antenna such as rectangular, circular, triangular and other types of geometries. The most popular configuration is rectangular microstrip patch antenna. In order to produce antenna for Wireless Local Area Network (WLAN) application, based on the factor, a rectangular microstrip patch antenna will be designed. This project will used the Flame Retardant 4 (FR4) and Roger4350 as a dielectric substrate in fabrication of the antenna.

1.3 Objective

i. To design a microstrip antenna for Wireless Local Area Network (WLAN) application with frequency of 2.4GHz.
ii. To simulate the antenna design by using Computer Simulation Technology (CST) Microwave Studio.
iii. To fabricate the microstrip antenna by using Flame Retardant 4 (FR4) and Roger4350 substrate.
iv. To investigate the performance of the antennas in term of return loss, operating frequency, bandwidth and Voltage Standing Wave Ratio (VSWR).

1.4 Scope

The main scope of this project consist of two parts which is software and hardware design. For the simulation part, a Computer Simulation Technology (CST) Studio will be used in order to design a rectangular microstrip patch antenna. For the hardware part, a rectangular microstrip patch antenna will be fabricated by using the different materials which is Flame Retardant 4 (FR4) and Roger 4350. The Network Analyzer will be used to measure S11, input impedance and Voltage Standing Wave Ratio (VSWR) while for the radiation pattern will be measured in anechoic chamber.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter reviews some similar previous work, related journals and researches which include microstrip antenna design that can contribute an ideas for completing this project. This chapters also will discuss about the performance of the antenna and the material that has been used to fabricate the antenna. This chapter is very important to know the performance of the antenna and to get a better performance of the antenna compared to the conventional antenna.

2.2 Basic of Antenna

There are many basic types of antenna element such as the dipoles, horn, slot, spiral, long wire, monopole, and there are also many different types of systems where these element can be arrange in some form of an array, either fixed or electronically controlled. Thus, the antenna can be divided into four types depends on their operating frequency, characteristics and capability. The groups are resonant antenna, broadband antenna, aperture antenna and electrically small antenna.

2.3 Microstrip Antenna

In its simplest configuration, microstrip antenna consist of radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch conductors normally is copper or gold. The radiating patch and feeding lines is usually photo etched at the dielectric substrate [6]. Figure 2.1 shows the structure of the microstrip patch antenna.

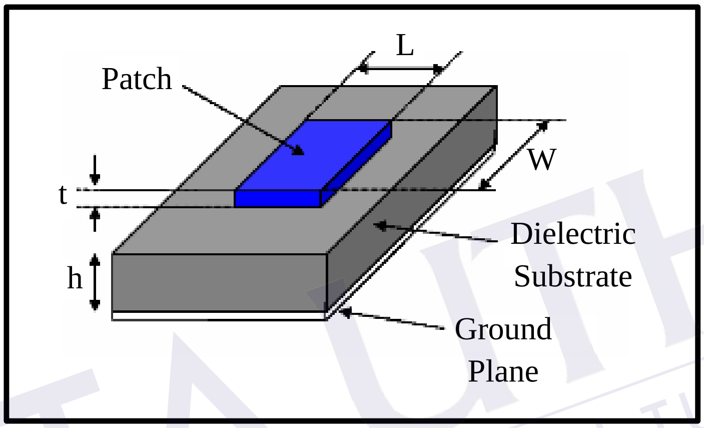

Figure 2.1 : Microstrip Patch Antenna Structure.

Based on the Figure 2.1, it shows the common microstrip antenna structure where W is the width of the patch, L is the length of the patch, t is the thickness of the patch and h is the height of the substrate. To achieve the great in antenna performance, a thick dielectric which have a low dielectric constant is needed. This will provide higher efficiency, larger bandwidth and greater radiation. But, in order to achieve this, larger antenna size will be produced. In order to reduce the size of the antenna which mean to produce a compact design, a higher dielectric constant which is less efficient and will contribute a narrower bandwidth will be used [6].

Microstrip antenna has several advantages compared to conventional microwave antenna. These types of the antennas are light weight, low volume and thin profile configurations, which can be made conformal. The cost of fabrication is also low. So, it can be manufactured in a large quantities [6]. For the polarization types, it can support both linear and circular polarization depending on the radiation pattern. Microstrip patch antenna also capable of dual and even triple frequency operations [6]. On the other hand, microstrip patch antennas also have some disadvantages. These type of antenna have a narrow bandwidth, low efficiency and also have a low gain [6].

2.3.1 Feed Techniques

Microstrip antenna feed techniques can be categorized in two categories which are contacting and non-contacting. In the contacting method, the RF Power is fed directly to the radiating patch using a connecting element such as a microstrip line. The microstrip line and the coaxial probe are examples of contacting method.

In the non-contacting, electromagnetic field coupling will be done to transfer the power between the microstrip line and the radiating patch. Techniques that are in these non-contacting methods are aperture coupling and proximity coupling [6]. The feed technique that was used in this project is the microstrip line feed. However, for the coaxial feed, it can be placed at any location to match with its input impedance. It provides narrow bandwidth and it is difficult to model. Figure 2.2 shows the coaxial feed of the antenna [6].

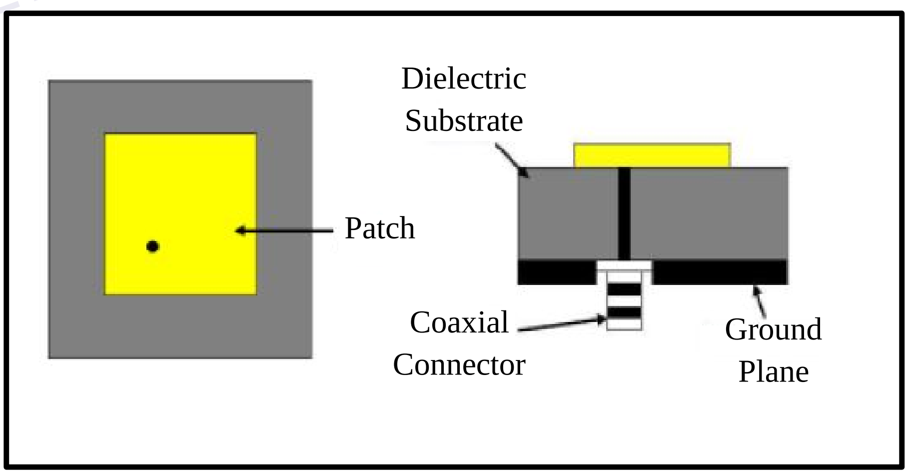

Figure 2.2 : Coaxial Feed of the Antenna.

2.4 Antenna Properties

The performance of the antenna can be determine by this important parameters which is radiation pattern, directivity, gain, half-power beamwidth, bandwidth, input impedance, polarization, reflection coefficient, Voltage Standing Wave Ratio (VSWR) and return loss.

2.4.1 Radiation Pattern

It is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. The radiation property of most concern is the two or three-dimensional spatial distribution of radiated energy as the function of the observer's position along a path of surface of constant radius [7].

2.4.1.1 Principal Patterns

For a linearly polarized antenna, the performance is usually described in terms of its principal E-plane and H-plane patterns. The E-plane is defined as the plane containing the electric-field vector and the direction of maximum radiation. The H-plane is defined as the plane containing the magnetic-field vector and the direction of maximum [7].

2.4.1.2 Radiation Pattern Lobes

A radiation lobe is a portion of the radiation pattern bounded by regions of relatively weak radiation intensity. A major lobe also called as the main beam is defined as the radiation lobe containing the direction of maximum radiation. A minor lobe is any lobe except a major lobe. A side lobe is a radiation lobe in any direction other than the intended lobe. Usually a side lobe is adjacent to the main lobe and occupies the hemisphere in the direction of the main beam. A back lobe is a radiation lobe which the axis makes an angle of approximately 180 degrees with respect to the beam of an antenna [7]. Figure 2.3 shows the radiation patter of a generic directional antenna.

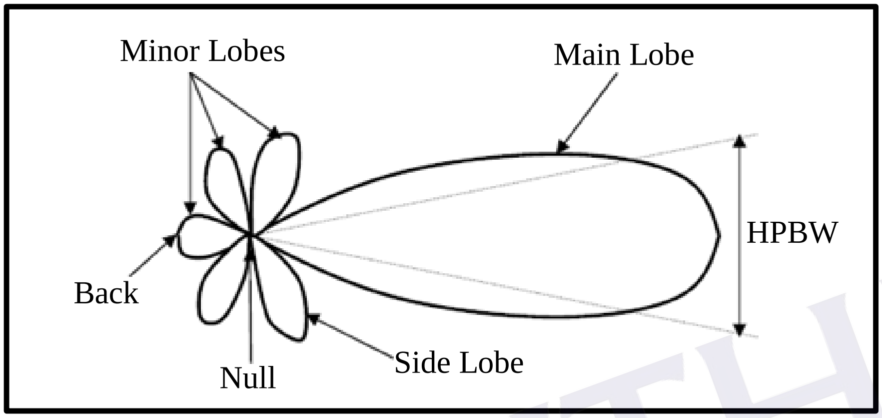

Figure 2.3 : Radiation Pattern of a Generic Directional Antenna.

2.4.2 Directivity

Directivity can be defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged of all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation intensity is implied [7]. If the direction is not specified, the direction of maximum radiation intensity can be expressed as

$$Dmax = Do = \frac{Umax}{Uo} = \frac{4\pi Umax}{Prad} \tag{2.1}$$

Where

D = directivity (dimensionless)

Do = maximum directivity (dimensionless)

U = radiation intensity (W/unit solid angle)

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